Investing in America's Future

Draft

National Science Foundation Strategic Plan

FY 2006 – 2011

National Science Foundation
WHERE DISCOVERIES BEGIN

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INTRODUCTION: STRATEGIC PLANNING IN A CHANGING LANDSCAPE

The National Science Foundation (NSF) was created over 50 years ago to be the premier agency supporting basic research at the frontiers of science, across all fields, and science education programs at all levels. Research supported by NSF has fueled many important innovations and thereby stimulated economic growth and improved the quality of life and health for all Americans. However, the context in which science is done is undergoing rapid change and NSF needs to respond to it.

RESPONSIBILITIES

The National Science Foundation Act of 1950 authorizes and directs NSF to initiate and support:

- Basic scientific research and research fundamental to the engineering process,
- Programs to strengthen scientific and engineering research potential,
- Science and engineering education programs at all levels and in all fields of science and engineering, and
- An information base on science and engineering appropriate for development of national and international policy.

ADDITIONAL RESPONSIBILITIES

Legislation and Presidential Directives added new requirements for NSF over time including:

- fostering the interchange of scientific and engineering information nationally and internationally;
- maintaining facilities in the Antarctic and promoting the U.S. presence through supporting and managing a vigorous US national research program in the Arctic and Antarctic; and
- addressing issues of equal opportunity in science and engineering.

A. INCREASING PACE, SCOPE AND IMPACT

Scientific discoveries are coming at an accelerating pace in virtually all fields, transforming the science and engineering landscapes and opening entirely new territory for exploration. The creation of knowledge – requiring ideas and people – takes place in a dynamic, complex, and competitive international environment.

Already visible on the horizon are path-breaking new avenues for investigation that were unimaginable only a few years ago. Building on decades of fundamental research, we are creating models of increasingly complex systems across multiple disciplines and scales. This research may lead to a new understanding of systems such as how networks of cells communicate, how species interactions create our biosphere, how simple human interactions collectively yield complex social behavior, and how basic physical forces power atmospheric and oceanic movements.

Science is increasingly global and of significant societal importance. Future investigations will require new generations of globally-engaged researchers working collaboratively across agencies and international organizations to apply the results of basic research – such as in ecosystems science, seismology, or basic energy sciences – to global challenges such as emerging infectious diseases, natural hazards, and the need for alternative energy sources.

B. NEW MODES OF INVESTIGATION

The way science and engineering are conducted is changing. This is due, in large part, to the expansion of networked cyberinfrastructure and to new techniques and technologies that enable observations of unprecedented quality, detail, and scope, as well as ways to begin to answer age-old questions that could not be approached before. New modes of conducting science employ revolutionary new sensor systems; involve massive databases, digital libraries, unique visualization environments, data accessibility, and complex computational models; and utilize exciting new research tools such as genomic sequencing, materials processing at nano-scales, and single-molecule chemistry. These advances have not only made it possible to reach the frontier faster, they have also increased by orders of magnitude the levels of complexity open to exploration and experimentation. Understanding this complexity and learning how humans can best harness it is a challenge. Despite the unprecedented nature of these transformations, change of even greater magnitude is likely as tools and technologies continue to progress.

Evolving in concert with these new tools are different ways of working within science and engineering. Discovery increasingly requires the expertise of individuals from different disciplines, with diverse perspectives, and often from different nations, working together to accommodate the extraordinary complexity of today's science and engineering challenges. The convergence of disciplines and the cross-fertilization that characterizes contemporary science and engineering have made collaboration a centerpiece of the science and engineering enterprise. The Internet has clearly demonstrated, on local to global scales, that an integrated cyberinfrastructure will be of ever-increasing significance for any nation that aspires to reap the benefits of new knowledge and innovation in the future.

The changes brought about by revolutionary discoveries and technologies are also altering the global economic and social landscape. Nations worldwide recognize that frontier research, innovation, technological infrastructure, and an educated population are powerful forces for economic growth and social prosperity. This awareness is raising aspirations and shifting science, engineering and technology from the periphery into the mainstream of policy attention and action. To maintain its position at the forefront of discovery and innovation, the U.S. has made a commitment to double investment over 10 years in key Federal agencies, including NSF, that support basic research programs in the physical sciences and engineering.

C. Improving Education and Workforce Development

Scientists and educators are working collaboratively to increase the effectiveness of math and science education. Discovery-based learning should be an integral feature of all levels of formal and informal education, from hands-on activities in kindergarten to public participation in research sample collection. As these and other practices take root, they are likely to transform education research and practice in ways that are not yet well understood. Science, technology, engineering and mathematics (STEM) education at all levels will continue to benefit from new technologies, such as information and communications technologies, and their potential for more engaging and inclusive learning and discovery. Access to interactive data sets, simulations, and up-to-date research results, as well as opportunities to interact with active researchers, have increased rapidly in K-12 classrooms and in complementary informal science education venues.

The current science and engineering workforce is aging, and for the future workforce we are inadequately tapping the talent pools of women, minorities and persons with disabilities, who remain underrepresented in science and engineering professions. These changing demographics in the U.S. mean that we need different approaches to excellence in education and mentoring so that all Americans can contribute to the capacity of the science and engineering workforce to meet future challenges. In addition, it is important to realize that some regions of the country have not yet developed the critical mass of research and innovation capacity that can propel them into the knowledge economy.

The U.S. has long benefited from an open-door policy that welcomes talent from abroad. Other nations are now adopting this policy, as well as providing incentives for students to pursue

Each year, NSF oversees about 35,000 active awards directly supporting more than 190,000 people – teachers, students, and researchers at every education level and across all disciplines in science and engineering. Merit review results in about 10,000 new awards each year from over 40,000 proposals submitted by the research and education communities.

their education at home or return from abroad, based upon their critical assessments of their future needs. Such policies are likely to put additional pressure on the future U.S. science and engineering workforce. The global economic issues of workforce, competitive positions of nations, and the need for collaboration on large-scale science projects require additional work. The nation needs to increase our interaction and cooperation with scientific organizations around the globe.

D. TAKING ACTION

Responding to these opportunities and challenges is a formidable task. The National Science Foundation's strategic plan and goals address both the approach to meeting them and the challenges presented. NSF will act as a change agent to affect this dynamic environment positively by supporting transformative research and promoting excellence in science and engineering education in ways that will fuel innovation, stimulate the economy, and contribute to the betterment of the quality of life and health for everyone. We will also nurture the vibrant and innovative science and engineering enterprise necessary to achieve these goals and stimulate broader participation in this enterprise throughout the nation. The strategic goals in this plan provide an overarching framework for progress in fundamental research and education; a framework that leaves ample room to experiment and adapt to changing circumstances. The strategies for future investments look toward and beyond today's horizons.

MATERIALS WORLD NETWORK

As the world's economies grow increasingly interdependent, international research partnerships are growing in importance. The ability to develop collaborations that create new value for the partners is often the limiting factor for progress in critical areas of science, engineering and technology. NSF supports international partnerships that foster international cooperation, build global research capacity, and advance the frontiers of science for the benefit of all.

A case in point is the Materials World Network, a global community of researchers and educators working across borders and disciplines, in developed and developing countries, to accelerate materials discovery and design. From the first alloying of bronze to the plastics revolution to the advent of biomaterials, the design of materials to fit our needs has transformed society. Now, materials scientists are on the brink of another revolution—designing and engineering materials by building in special properties, atom by atom. Such new materials may help to increase energy efficiency, promote green manufacturing, improve health care, develop information and communications systems, and provide modern and reliable transportation and civil infrastructure. To maximize the global benefits, NSF together with partners from abroad established the Network, which now reaches nearly every region of the world. The Network brings together a diverse community to address global challenges through materials research, technology, and education. Strategic project areas include research, education, facilities, and cyber-infrastructure.

I. Core Values

The NSF core values are both essential and enduring tenets that influence everyone in the organization. The distinctive culture they generate gives NSF its integrity and unique character. At NSF, we are

- ***Visionary:*** imagining the future, working at the frontier, realizing the full potential of people, furthering promising ideas wherever and whenever they arise, and encouraging creativity and initiative.
- ***Dedicated to Excellence:*** continually improving our ability to identify opportunities; optimally invest the resources entrusted to us; manage a diverse, capable, motivated organization; reward accomplishment; and share our best insights with others.
- ***Broadly Inclusive:*** seeking and accommodating contributions from all sources while reaching out especially to groups that have been underrepresented; serving scientists, engineers, educators, students, and the public broadly across nation; and exploring every opportunity for partnerships, both nationally and internationally.
- ***Accountable:*** operating with integrity and transparency, maintaining quality and relevance in administration, management and oversight.

II. Mission, Vision, Goals and Objectives

NSF invests in the best ideas generated by scientists, engineers and educators working at the frontiers of knowledge, and across all fields of research and education. Our mission, vision, goals, and objectives are designed to maintain and strengthen the vitality of the U.S. science and engineering enterprise.

Our Partners Share Our Core Values

NSF draws on the vision of the research and education communities for creativity and for innovative ideas that move science and engineering across new frontiers. We mirror their dedication to excellence as we work together to review thousands of proposals to select the exceptional ones that become part of the NSF investment portfolio. We ask them to include diverse perspectives as they explore new opportunities and partnerships, while we attempt to broaden our own.

International Polar Year

NSF continually seeks out research opportunities with the potential to transform entire areas of science and engineering, and to propel understanding far beyond current frontiers. One highly visible example is the International Polar Year (IPY). From March of 2007 to March of 2009, NSF will lead an interagency effort to comprehend the Earth's extreme latitudes at scales from the global to the molecular, train new researchers for careers in science and engineering, and to communicate to the public about the importance of the polar regions.

In the process, researchers will begin to answer some of the most profound questions in geoscience and biology. Among them:

- What is the history of the planet's vast ice sheets? How did they form, how did they respond to past climate patterns, how are they changing, and what is the prospect for rapid alteration?
- How does life adapt itself to extreme cold and prolonged darkness? How are those adaptations manifested in cellular structure and genome?
- What is happening in the Arctic? How are the region's physical, chemical, biological and human components interrelated? And how can we create a comprehensive, long-term observational network to supplant the scattered and uncoordinated record of measurements that now exists?

The International Geophysical Year 1957-1958 ushered in a new era of global science and international cooperation, witnessed the creation of more than 50 research stations, and paved the way for the Antarctic Treaty. Half a century later, the IPY will enable an even greater expansion in the depth and breadth of knowledge through multi- and interdisciplinary projects, the creation of long-awaited infrastructure, the collection of unprecedented datasets, and the creation of new, more expansive international collaborations.

The new South Pole Station

Toolik Field Station, Toolik Lake, AK
Credit: Sarah Behr

A. Mission

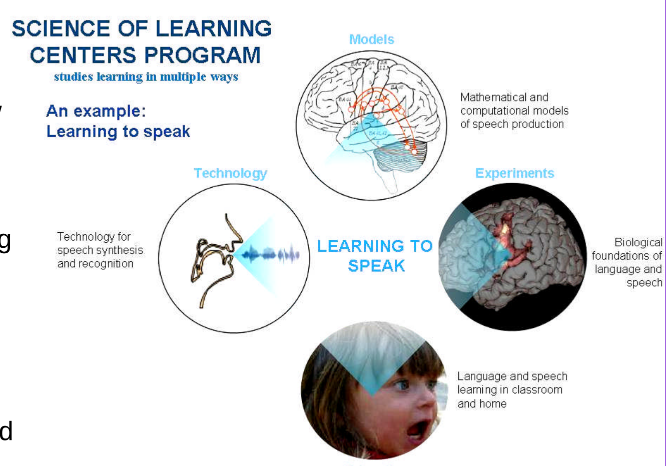
To promote the progress of science; to advance the national health, prosperity, and welfare; to secure the national defense (NSF Act of 1950).

This mandate, following a course for supporting American science and engineering that was originally proposed in *Science, the Endless Frontier*[1], continues to guide and inspire us to advance beyond the current limits of science and engineering knowledge in a rapidly changing world.

NSF Centers

NSF Centers, (e.g., Science and Technology Centers, Engineering Research Centers, Science of Learning Centers) support interdisciplinary research of a scope, scale, and complexity beyond the resources of any individual investigator or small group. Centers also provide rich environments for the interdisciplinary training and mentoring of undergraduate students, graduate students, and post-doctoral fellows, as well as K-12 educational partnerships and public outreach. The Center model promotes opportunities for cross-fertilizations of ideas between and among theoretical and experimental scientists and students, as well as between the scientists and students and the educators and technologists who turn their results into real-world applications. One example is Boston University's Center for Learning in Education, Science, and Technology (CELEST), a Science of Learning Center.

A Science of Learning Center seeks to advance our knowledge of learning in all its forms, from the digital to the societal, over as broad a range as possible. This may include the chemical and biological basis of learning; the psychological, social, organizational and pedagogical aspects of learning; machine learning; mathematical analyses and models of learning; and more. At CELEST researchers study and model how the brain learns to adapt in real time to complex and changing environments. CELEST scientists address this question across multiple levels of analysis, from single neurons, to neural networks, to whole brain and behavior. To truly understand the linkages between brain and behavior, one must study each in conjunction with the other, from neurons and synapses, to sensory perception, to learning and memory, to complex behaviors. The development of new algorithms, based on knowledge of these processes, can then be used to solve outstanding technological problems presented by uncertain and ever-changing data. CELEST scientists also work with educators to bring models of how mind and brain work into math and science curricula at all instructional levels.



B. Vision

Advancing discovery, innovation, and education beyond the frontiers of current knowledge, and empowering future generations in science and engineering.

C. Strategic Outcome Goals

The four interrelated goals adopted by the National Science Foundation establish an integrated strategy to deliver new knowledge at the frontiers and meet vital national needs. Although similar to the previous Strategic Plan's goals of Ideas, People, Tools, and Organizational Excellence, the new goals are derived from the strategic priorities recently established in the *National Science Board 2020 Vision for the National Science Foundation*[2] and put greater emphasis on ultimate outcomes.

Discovery

Foster research that will advance the frontiers of knowledge, emphasizing areas of greatest opportunity and potential benefit, and establishing the nation as a global leader in fundamental and

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[1] Bush, V. (1945). http://www.nsf.gov/about/history/vbush1945.htm

[2] NSB 05-142. http://www.nsf.gov/pubs/2006/nsb05142/nsb05142.pdf

transformative science and engineering.

LEARNING

Cultivate a world-class, broadly inclusive science and engineering workforce, and expand the scientific literacy of all citizens.

RESEARCH INFRASTRUCTURE

Build the nation's research capability through critical investments in advanced instrumentation, facilities, cyberinfrastructure, and experimental tools.

STEWARDSHIP

Support excellence in science and engineering research and education through a capable and responsive organization.

D. OBJECTIVES

NSF has identified two crosscutting objectives that apply to each goal and are essential to advancing the mission and vision. Expert evaluations, described in the Appendix, will periodically assess the progress in working toward these two objectives for each of the four strategic outcome goals.

TO INSPIRE AND TRANSFORM

NSF advances scientific discovery by supporting revolutionary and distinctive new capabilities—those innovations in research and education that move discovery well beyond the boundaries of current knowledge. NSF will continue to recognize this potential for transforming the science and engineering community and providing the creative spark that ignites it.

NSF cultivates the same creative spark in young people, and develops innovative pathways to engage them at the frontiers of discovery and facilitate their entry and advancement in the science and engineering workforce. NSF will inspire the next generation; promoting excellent science education through timely access to exhilarating discoveries in classrooms while partnering with museums and other organizations that use methods of informal science education to bridge the gulf between scientific advances and public understanding.

NSF supports the development of infrastructure that gives researchers access to new territory impossible to explore without it, including multiple use and distributed instruments and facilities, and comprehensive, next-generation cyberinfrastructure. NSF-funded centers enable academic institutions and their partner organizations to integrate discovery, learning and innovation on scales that are large enough to transform important science and engineering fields and cross-disciplinary areas through extensive organized efforts. They also provide opportunities for students to broaden their research horizons and industrial partners to interact with top academic researchers.

FAB LABS

Around the world, from high-school students to rural farmers, people are now being given the opportunity to design and fabricate sophisticated devices from scratch, thanks to an NSF-supported program called "Fab Lab." Short for "fabrication laboratory," a Fab Lab is a portable, dishwasher-sized array of equipment that combines highly flexible, user-friendly CAD/CAM and modeling software with a suite of industrial-grade tools including a laser cutter and milling machine. For less than the price of a compact car, it gives users the technology to describe, design, and build just about anything from inexpensive and readily available materials. The goal is to help people who traditionally have lacked access to sophisticated resources use advanced information technologies to develop and produce solutions to local problems.

The idea for Fab Lab arose at MIT's Center for Bits and Atoms, launched by NSF funding to explore the interface between computer science and physical science. Fab Labs have been tested around the world: In Ghana, users have devised antennas and radios for wireless networks, and solar-powered machinery for cooking, cooling and cutting. In Norway, the units have produced wireless networks and animal radio collars to aid nomadic herding of reindeer. In India, users are making agricultural instrumentation, testing milk for quality and safety, and tuning diesel engines to run more efficiently, particularly with local biofuels. And, in Boston, Fab Lab users make jewelry, toys and crafts using recycled materials from the community.

8 year old Valentina Kofi with a circuit board she made herself.
Courtesy Center for Bits and Atoms, MIT, 2004

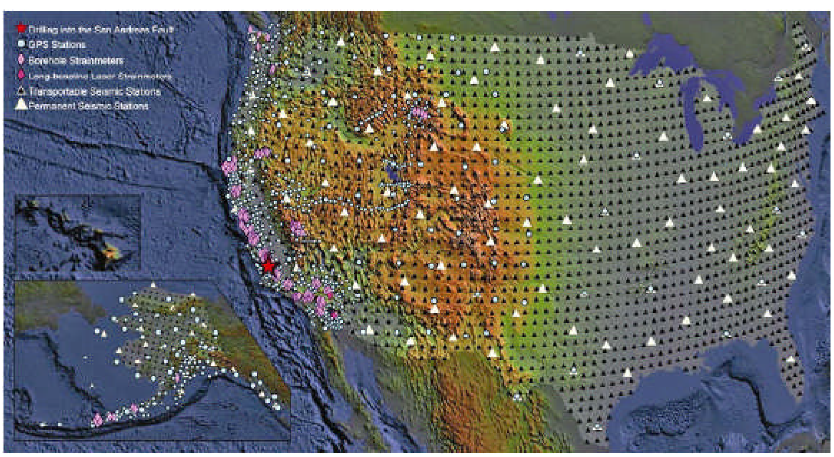
EARTHQUAKE SCIENCE AND ENGINEERING

Earthquakes are among the most complex terrestrial phenomena. Taken from end to end, the challenge comprises understanding the loading and failure of tectonic faults, the generation and propagation of seismic waves, the response of surface sites, and, in application to seismic risk, the damage caused by earthquakes to the built environment and the preparation and response of communities and disaster managers. Building on decades of funding earthquake-related science and engineering and seismic measurements, NSF is now poised to contribute to great new advances in our knowledge of the structure and evolution of the North American continent and understanding of earthquakes and seismic systems.

With NSF funding, the Southern California Earthquake Center (SCEC) has developed a community modeling environment (CME) for simulating earthquake processes using terascale computing facilities. Already, simulations have delivered new predictions about seismic hazards from California's San Andreas Fault system. During its next phase (2007-2010), the CME project will focus on three computationally demanding science objectives: extending simulations of ground motions to investigate the limits of ground-motion prediction; improving the resolution of dynamic rupture simulations, and computing and validating seismic hazard maps.

The Network for Earthquake Engineering Simulation (NEES) is NSF's first distributed network cyberinfrastructure research facility. It is a national, shared use experimental resource linking together 15 facilities located at universities across the U.S. The network enables collaboration and advanced research and education based on experimentation and computational simulations of earthquakes and how buildings, infrastructure, coastal regions, and geologic materials perform during seismic events. NEES will advance understanding and improve the design and performance of the Nation's constructed civil and mechanical infrastructure when subjected to earthquake excitation and tsunamis.

The EarthScope Facility, a distributed, multi-purpose geophysical instrument array, will provide the next generation web of interrelated measurements required to fuel these and other earthquake-related research activities. EarthScope instrumentation is expected to inhabit nearly every county within the U.S. over the lifespan of the program. Partners include USGS, NASA, the Department of Energy, and the International Continental Scientific Drilling Programme, and may also include state and local governments, geological and engineering firms, and Canadian and Mexican agencies. Over 3,000 earth scientists and students are expected to use the facility annually.



The complete EarthScope footprint. Locations of the 2400 campaign stations will be determined through annual proposal review; many of these sites likely will change annually.
Credit: Earth Scope

NSF seeks to be a trailblazer in its own administration and management, with organizational structures, learning environments, business practices, and merit review that serve as models for research agencies around the world.

In all its activities, NSF endeavors to communicate the wonder of exploration, the excitement of discovery and the beauty of science and engineering.

TO GROW AND DEVELOP

NSF will continue to strengthen fundamental research across the full spectrum of science and engineering. The majority of our research funding supports individual investigators and small groups of researchers. Efforts are particularly important for fields that are critical to the U.S. science and engineering enterprise but receive little support from other sources. NSF ensures the health of core science and engineering fields as they grow, develop, and ultimately converge into new disciplines. We help support the underlying research enterprise that mission agencies and industry draw upon to accomplish their objectives.

NSF provides leadership within an extended network of schools, colleges, universities; museums; professional associations; other research foundations and agencies; and small and large businesses—all engaged in science and engineering research and education. We encourage this broad array of institutions, in all locations throughout the nation and from every sector, to participate fully in the nation's science and engineering enterprise. NSF also aims to broaden participation by drawing on all of the nation's talent and reaching out especially to underrepresented groups.

NSF is the principal source of support for investigations to improve science and engineering education from early childhood through undergraduate and graduate studies, including public outreach, and for research that develops models for teaching and learning. Recognizing their essential partnership in this effort, NSF also supports 'informal science' organizations and institutions, for example, science centers, aquaria, museums and through educational programming, where many Americans acquire science information and additional learning. These efforts increase interest, engagement, and understanding of science, engineering and technology by individuals of all ages and backgrounds within a variety of different educational settings.

NSF commits to being a learning organization that internally encourages, rewards, and values the contributions of its talented people. As proposals become increasingly complex and interdisciplinary, NSF adapts and responds to continue to find and support excellence in science and engineering research and education. We promote professional integrity in this work and in the research and education we support.

III. Priorities for Investment

NSF establishes well-defined priorities to allocate investment funds and internal resources effectively. The priority-setting process draws upon contributions from a broad cross section of the science and engineering community, as well as NSF Advisory Committees. The overall strategic goals and objectives are set by our leadership, with additional guidance from the Administration and Congress. Priorities may reflect emerging opportunities of great promise, address pressing challenges, or respond to critical national needs. They may encompass all NSF activities and require sustained levels of investment over many years, or they may be more narrowly focused and change from year to year as promising opportunities arise.

EAPSI

The frontier challenges of science and engineering are increasingly global. Future generations of the U.S. science and engineering workforce will need to collaborate across national boundaries and cultural backgrounds, as well as across disciplines. NSF's East Asia and Pacific Summer Institutes (EAPSI) program provides hundreds of U.S. science and engineering graduate students with a hands-on international research experience and a head start in developing the teamwork, partnering and communication skills necessary to succeed in the global research arena.

Each year, the EAPSI program sends American graduate students to Australia, China, Japan, Korean, and Taiwan (New Zealand will be added in 2007) where they work side-by-side with professors and peers from the leading universities and laboratories in those countries on science and engineering challenges of mutual interest. The cross-cultural experience exposes EAPSI students to the diversity of ideas that drives innovation, and it fosters their becoming more effective communicators. In recent years, participants conducted research in areas ranging from humanoid robotics, nanofabrication and earthquake engineering to evolutionary biology, sensory integration, bionanomaterials and science and technology education. For example, a student from Texas A&M University who conducted field research at China's Wolong Nature Reserve completed a preliminary study on the ability of giant pandas to recognize their kin, and she facilitated an agreement between her host institution and the Reserve to set up a live web "panda cam," giving other researchers and the broader public the ability to observe panda behavior and learn about efforts to conserve the pandas' habitat.

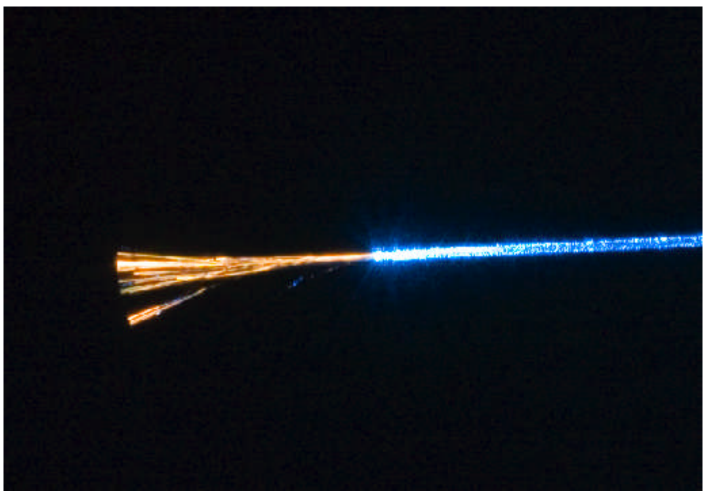
U.S. students participating in the EAPSI program; shown exploring the Great Wall of China

Nanoscience and Nanotechnology

Research advances at the nanoscale continue to inspire new technologies that will have a profound impact on society. Increasing control of matter and energy at the molecular level is already leading to revolutionary breakthroughs in such critical fields as advanced computing, communications, materials development and medicine:

- The nanofabrication of miniature electronic components may revolutionize information processing. From nanowire circuits to quantum dots to single-molecule transistors, recent advances promise a new generation of computing devices far smaller than today's, and with lower power requirements.
- In communications, nanostructures are dramatically reducing the size of signal-processing components and have led to unanticipated new abilities to control light beams for the next wave of photonic equipment.
- In medicine and biology, ultra-miniaturized sensors and fluid channels are ushering in a new era of tiny diagnostic and detection devices that can determine the presence of target compounds, and function as artificial taste and smell organs. Other devices use nanoscale structures to detect specific DNA strands or reagents, producing "laboratories on a chip"

As the lead federal agency for the National Nanotechnology Initiative, NSF provides critical support for efforts in fundamental nanoscale science and engineering, as well as research to understand the likely impacts of nanotechnology on society. The integration of education with research at this nanoscale frontier—whether in relation to the fundamental physical sciences, materials science, engineering, biological sciences, information science or social sciences—will be essential for developing the full cadre of researchers, technologists, engineers, and the skilled workforce necessary for realizing the maximum benefit from this new field of knowledge.



Semiconductors encased in glass may help define the next generation of nanoscale devices. *Center for Nanoscale Science, Penn State University / University of Southampton*

A. Long Term Investment Priorities

For 2006-2011, NSF will seek out creative means and strategies to enhance progress on a variety of long term priorities associated with our strategic goals. These priorities are central to maintaining the vitality of the U.S. research and education enterprise and demonstrate our commitment to eminence as a steward of the nation's resources.

Discovery

- ***Promote research that encourages a holistic perspective***. NSF will emphasize investigations that cross disciplinary boundaries and that take a systems approach to complex problems (e.g., the neural basis of behavior, natural hazards, and grid technologies).
- ***Investigate the human and social dimensions of new knowledge and technology.*** NSF will integrate research on ethics, safety considerations, and virtual communities from the outset in new research and in the applications of emerging technologies.
- ***Further U.S. economic competitiveness.*** NSF has major roles in the American Competitiveness Initiative in the areas of research, infrastructure, and education. We will promote innovations that improve the nation's research capability, particularly in the physical and engineering sciences, and spur the translation of research results into new applications and products.
- ***Foster research that focuses on living sustainably on the Earth***. Such research may range from investigations of deep oceans to urban centers and from basic energy science to climate science, improving our understanding of the links between human behavior and natural processes.
- ***Advance fundamental research in computational science and engineering, and in applied mathematics and statistics.*** Progress in these fields is needed to power the use of next-generation cyberinfrastructure and networking that will drive discovery in every field of science and engineering.

LEARNING

- ***Build strong foundations and foster innovation to improve K-12 teaching, learning, and evaluation in science and mathematics.*** NSF will support education research, develop model programs and effective assessment methodologies, disseminate best practices, and broaden partnerships with others, especially other federal agencies, to achieve results.
- ***Advance the fundamental knowledge base on learning, spanning the broad spectrum from animals and humans to machines.*** Fundamental knowledge – from neuroscience to sociocultural dimensions – will permit researchers to address a wide range of societal challenges, including understanding how people learn, best educational practices, workforce preparation, and facilitating the adoption and integration of new technologies in society
- ***Develop methods to effectively bridge critical junctures in the STEM education pipeline***. These will focus on junctures between K-12 and undergraduate education and will support continuous pathways to a variety of career options.
- ***Prepare a globally engaged STEM workforce.*** In keeping with our mandate and roles in the American Competitiveness Initiative, NSF will focus on broadening participation in STEM disciplines and will work with industry partners to ensure that STEM education and workforce preparation provide the skills and knowledge needed to flourish in a global knowledge economy.
- ***Integrate research with education, and build capacity.*** NSF will develop research and education capacity across the full spectrum of the nation's educational institutions, and utilize advanced cyberinfrastructure to transform the way we learn, teach, and prepare an IT-literate workforce. NSF will renew the focus on 2- and 4-year colleges and minority serving institutions, and promote faculty enrichment programs,

INFORMAL EDUCATION

By the time our children reach the age of 18, they have spent approximately 12% of life in school, approximately 33% of life sleeping, and perhaps10-12% of life eating, bathing, and performing other daily routines. This leaves over 40% of time that is likely spent in informal or unstructured activity. It is safe to say that as much, if not more, actual learning takes place in this 40% as occurs in their formal education. This is why; in addition to investments in curriculum development, teacher enrichment, and formal education programs; NSF invests heavily in informal math, science, and engineering education. If these subjects can be presented in ways that children (and adults) enjoy and chose for entertainment, the impact can be enormous.

Film is an entertainment medium of choice for most Americans, and athletes are our heroes. NSF partnered with the Partners Health Care, National Geographic, and others to take viewers on a spellbinding ride through the Tour de France, and simultaneously through the human brain. The movie combines spectacular big-screen footage of the race with state-of-the-art computer animations of the human brain and describes how each new experience stimulates brain growth and adaptation, and how the brain responds to experience and challenge in ways we are only just beginning to understand.

Credit: Partners/National Geographic

Credit: SAO/ASTC

Museums also have a big role in informal education, particularly when they are able to link displays and special events to formal education requirements. NSF partnered with NASA to fund the Harvard-Smithsonian Center for Astrophysics and Jeff Kennedy Associates, Inc. to produce "Cosmic Questions: Our Place in Space and Time," a 5,000-square-foot traveling exhibit that answers such questions as: What is the universe like? Was there a beginning to time? How do we fit into the cosmos? The exhibit invites visitors to explore their own connections to the universe; find out the latest on unsolved mysteries, such as black holes and the existence of extraterrestrial life; and discover what it's like to be an astronomer uncovering clues from the cosmos hidden in the faint light of distant galaxies. The result is a highly visitor-friendly exhibition about an extremely complex and difficult subject.

curricular improvements, and access to research instrumentation. NSF will enhance opportunities for partnerships among community and technical colleges, 4-year colleges, and research intensive universities.

- ***Engage and inform the public in science and engineering through informal education.*** NSF will focus on improving STEM literacy and developing new strategies that explicitly encompass both formal and informal education and have the potential to improve NSF's impact on the nation's critical needs for a scientific and technically literate citizenry, a skilled workforce, and a vibrant research community.

RESEARCH INFRASTRUCTURE

- ***Fill the gaps in our ability to provide enabling research infrastructure***. Raise current limits on instrumentation funding opportunities, where appropriate, to allow for funding of needed mid-sized instrumentation.
- ***Continue to support the next generation of transformational large facilities.*** NSF will foster the development of new capabilities, technologies, and instrumentation needed for the next generation of major research equipment and facilities.
- ***Develop a comprehensive, integrated cyberinfrastructure to drive discovery in all fields of science and engineering.*** NSF will initiate the first steps toward the development of a petascale computing facility; investigate the development of a next-generation Internet; and advance a wide variety of generic and domain specific cyberinfrastructure projects supporting global-scale research and education communities.
- ***Strengthen the nation's collaborative advantage by developing unique networks and innovative partnerships.***

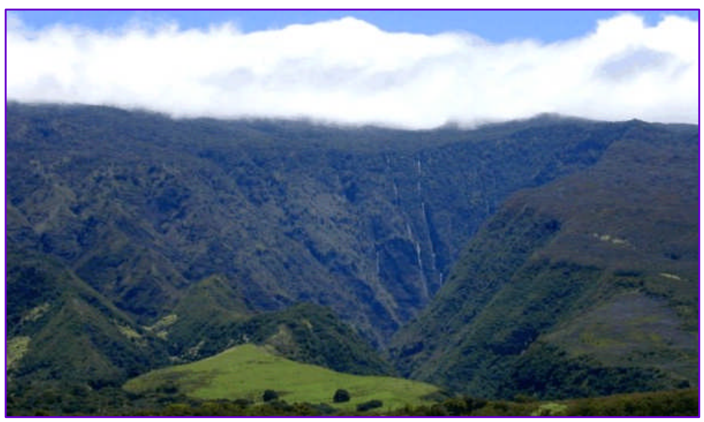
EPSCoR

Our future prosperity depends on a continuous supply of knowledge and innovation – discoveries that will solve the challenges of today, and will tomorrow bring a better quality of life, new technologies, and even completely new industries. But discovery doesn't just happen. It requires an effective, interactive networks of scientists, engineers, and educators to elaborate ideas; equipment and infrastructure needed to test those ideas; and diverse sources of support to help turn ideas into reality. A robust national network will have distributed capacity, employ the talents of a broad segment of the population, and sustain itself through excellence in education and infrastructure.

Creating and sustaining those conditions is a major goal of NSF's Experimental Program to Stimulate Competitive Research (EPSCoR). EPSCoR is a joint program of NSF and several U.S. states and territories that promotes the development of the states' science and technology resources through partnerships involving universities, industry, state and local government, and the Federal research and development enterprise. EPSCoR operates on the principle that aiding researchers and institutions in developing research capacity and infrastructure will maximize the potential for the state's research efforts to contribute solutions for society's challenges and advance economic growth.

A new West Virginia EPSCoR award will create a world-class research capacity in molecular recognition for biometric applications involving West Virginia University, Marshall University, and West Virginia State University. The research could lead to robust, low-cost instruments with multiple applications in homeland security, health, forensic science, and other fields. The program's partnership with West Virginia State University, a historically black university, will also target the integration of research with education and the recruitment of underrepresented students and faculty into the state's science and technology enterprise.

Another recent EPSCoR award will exploit the unique environment of the Hawaiian Islands, a natural laboratory for investigating ecological and genetic factors that govern ecosystem evolution adaptation to environmental change. The award will fund cyberinfrastructure and advanced environmental sensor technology, evolutionary genetics and ecosystems research, educational outreach, and recruitment and retention activities focused on Hawaii's diverse population. It promotes exciting science; responsible stewardship of Hawaii's ecosystems; and the development of technologically literate, critically thinking citizens for Hawaii's 21st Century workforce.



East Maui, Hawaii: Tropical Montain *Credit: USGS*

NSF will connect science and engineering researchers in academic organizations, industry, and informal science institutions both nationally and internationally to leverage intellectual capacities.

STEWARDSHIP

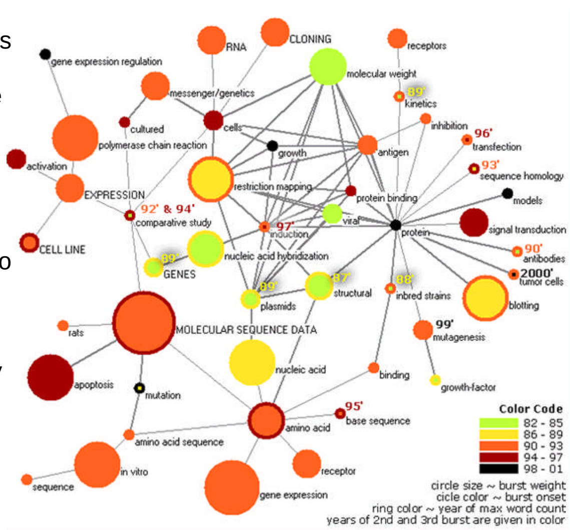
- ***Strengthen our traditional partnerships and develop new collaborations with other agencies and organizations.***
- ***Expand efforts to broaden participation from underrepresented groups and institutions in all NSF activities.***
- ***Improve our processes to recruit and select highly qualified reviewers and panelists.*** Potential new reviewers will be recruited and new investigators automatically added to an integrated, Foundation-wide database of reviewers, providing an increasingly diverse catalog for future selections of highly qualified reviewers. Reviewers and panelists will reflect the diversity in our community.
- ***Recruit, hire and empower highly qualified professional staff reflecting the diversity of our community.*** Program Officers, Division Directors, and other scientific and engineering professional staff are the principal means by which NSF projects values and receives ideas from the science, engineering and education research communities. It is critical that NSF continue to attract and, for permanent staff, retain scientists, engineers and educators with the necessary expertise, experience and impeccable reputations to act as stewards of national research and education programs.
- ***Develop mechanisms to improve training and mentoring for Program Officers.*** NSF will increase efforts to identify and disseminate best program management practices. Training and development is particularly important for "rotators" who bring valuable

SCIENCE OF SCIENCE POLICY

In response to rising concerns about the nation's global competitiveness, NSF has begun a wide-ranging inquiry into the social science of science policy: how the national research and development systems work, how to nurture innovation, how to measure science and technology indicators, and how to direct our investments. The long-term goal is to provide science policy makers with the same kinds of analyses and advice that economists now provide for the makers of fiscal and monetary policy. The NSF effort, which has two main elements, will be coordinated with similar efforts in several other federal research agencies:

- The measurement component seeks to develop a more scientifically rigorous, evidence-based approach to prioritizing research investments, and then monitoring the return on those investments. Research in this area will build upon NSF's already substantial effort in science and engineering statistics, first by developing new kinds of measurements and analytical tools; and second, by forging easy-to navigate links among the databases that already exist, whether in the private sector, in local, state and federal agencies, or internationally.
- The research component will seek to achieve an integrated understanding of national and global research and development systems and the process of innovation itself, from the "aha" moment in an individual brain, to a new product's debut in the marketplace, to a solution for a pressing societal challenge. The intent is to take as broad a view of the process as possible, bringing in perspectives from behavioral science, engineering, economics, and virtually every other discipline funded by NSF.

Meanwhile, NSF-funded researchers are developing tools to help individual investigators and science managers navigate through a global knowledge store that is doubling every 18 months or so. A prime example is the fast-emerging field of "mapping science," in which advanced algorithms are used to correlate data from science and engineering databases such as publications, grants, patents, and conferences, and to display the information as a two-dimensional map of a scientific area. This approach allows users to drill down to specific information on individual publications. But it also gives them vivid insight into rapidly evolving research areas and the relationships among them.



Mapping Topics and Topic Bursts in PNAS
Ketan Mane and Katy Börner (2004) PNAS, 101
© by The National Academy of Sciences

expertise and new ideas to the organization but stay for a limited amount of time, normally less than two years.

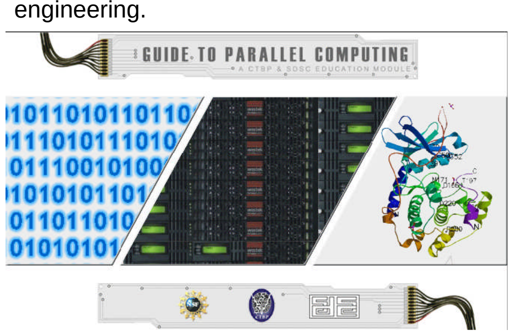
- ***Implement the Human Capital Management Plan.*** The plan was developed to strengthen management of NSF workforce, increase timeliness of recruitments, improve employee retention and recognition, and ensure development opportunities to meet future requirements and challenges.
- ***Enhance NSF as a learning organization***. NSF will provide continuing education, process enhancements, and opportunities to share best practices to enable continuous improvement. NSF will continue to be a great place to work and a model Equal Employment Opportunity (EEO) agency.
- ***Continue as an exemplar in science ethics.*** NSF will utilize standards, best practices, and institutional change that maintain and further build public trust in this area.
- ***Improve the transparency, consistency, and uniformity of the merit review process.*** NSF will promote ways to boost the identification and funding of projects with the potential to transform fields of scientific and engineering research. Successful technologies and techniques will be expanded to aid in assigning proposals to the most appropriate panels and to ensure that the set of ad hoc reviewers and panelists have the breadth and expertise for the set of proposals under consideration.
- ***Promote award balance and flexibility***. NSF will identify and implement program announcement and solicitation process improvements to achieve appropriate balances between proposal success rates, award sizes and award duration; encourage potentially transformative proposals; and provide flexibility to respond to specific opportunities and needs.
- ***Enhance processes for management and oversight of large facilities***. NSF will continuously improve our practices in the development, construction and operations of major research equipment and large facilities projects.
- ***Reach out, especially through cyberinfrastructure-enabled virtual methods, to the various communities we serve.*** NSF

COMPLEXITY AND EMERGENCE

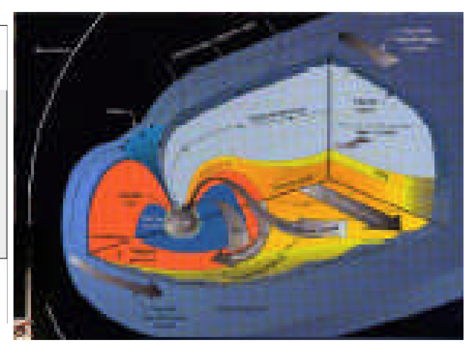
Nature abounds with examples of complex systems that show emergent phenomena, patterns of structure or behavior seen at one scale of a system that arise from interactions among system components at other scales of length, time, or number of components. Examples include the beating of a heart, the biological origin of a thought, the evolution of weather patterns, and the dynamics of some economic phenomena.

- Complex systems are ubiquitous and to understand them requires contributions from multiple disciplines. Recent mathematical advances have advanced the study of complex problems in geospace. These problems couple phenomena occurring at atomic scales with those occurring at astronomical scales, for example through the study of electromagnetic processes that control plasmas.
- The cross-fertilization of ideas and methods from biology and chemistry with those from the physics of complex systems has led to new approaches to a variety of critical issues including the evolution and functioning of genetic regulatory networks, the specificity of protein-protein interactions, the dynamic control of cell motility, and the synaptic mechanisms underlying learning.
- Analogies from the life sciences are motivating the design of self-assembling and self-repairing materials.
- Communities of researchers – spanning disciplines from engineering and geosciences to behavioral science – are working together to forecast, prepare for, and respond to natural and human-induced disasters.

NSF funding to improve understanding, modeling, and harnessing of complex systems will have far-reaching consequences across the entire spectrum of science and engineering.



Training at multiple levels, from undergraduate to senor investigators, is integrated into the research efforts at the Center for Theoretical Biological Physics, University of California San Diego



A schematic of the complex system of plasmas and electric currents that characterize the regions of near-earth space

BUILDING SCIENCE AND ENGINEERING CAPACITY

NSF is exploring new models and new partnerships for encouraging the nation's young people to study science and engineering and broadening their participation in these fields. One critical time period for students considering science and engineering careers is the undergraduate years. NSF's Research Experiences for Undergraduates (REU) and Undergraduate Research Collaboratives (URC) reach out to a diverse range of science and engineering undergraduates. The excitement of participating in meaningful research can crystallize a career direction and provide the essential motivation for continued study. REU and URC awards particularly target students who might otherwise have no opportunity to participate in research during their critical undergraduate years.

The URC Program combines a focus on first- and second-year college students with striving to improve the research capacity, infrastructure, and culture of participating institutions. Projects allow students to create new knowledge that is potentially publishable by providing exposure to research of contemporary scientific interest that is addressed with modern research tools and methods. The participation of two-year institutions that traditionally have been outside the research mainstream has been especially noteworthy. Nearly half of all undergraduate students attend community colleges, and, without such interventions, those students might otherwise overlook promising, productive careers in science and technology. Sample themes from projects already underway include biodiesel fuels; solar-energy conversion; chip-based chemical analyses; nanoscale materials; and molecular characterization of air, water, and soil samples.

The REU program funds both sites and grant supplements. Supplements typically provide support for one or two undergraduate students to participate in research, as part of a new or ongoing NSF-funded research project. REU Sites have a well-defined common focus that enables a cohort experience for students. One REU site is located at Prairie View A&M University (PVAMU) in Texas, a historically black university. The students participate in frontier space weather and space physics research at the Prairie View Solar Observatory (PVSO), a one-of-a-kind facility. Undergraduates in the program have the opportunity for hands-on experience processing and analyzing data, producing professional reports, and working with multiple solar telescopes, as well as learning computer programming and computer simulation. PVSO faculty and research staff members mentor students in individual research experiences.

At PVAMU, Dr. Sorin Pojoga assists an undergraduate student in a solar physics project.

will utilize new information and communications technologies as they become available to achieve and communicate mission outcomes. NSF will be open and transparent in our communications with the public.

B. FUTURE INVESTMENT CONSIDERATIONS

Based on its strategic outcome goals and objectives, NSF identifies strategic areas for future investments by balancing a variety of concurrent and equally-important factors. Proposed investments will be evaluated against this matrix of considerations. (Individual projects are evaluated using the merit review criteria described in the Appendix.)

- ***Alignment:*** Align with NSF's mission, vision, goals, and objectives. Deciding factors include whether investments lie within the bounds established by the NSF strategic plan, effectively address multiple goals, and do not duplicate the efforts of other agencies or institutions.
- ***Budget:*** Balance investments with funding levels. Deciding factors include whether the proposed level of investment is commensurate with the opportunity, level of risk, relevance, and potential impact.
- ***Integration of Research with Education:*** Create bonds between learning and inquiry. Deciding factors include whether investments present a rich environment for encouraging future scientists, engineers, and educators and provide opportunities for teachers and students to participate in research activities at the K-12 and undergraduate levels as well as graduate and postdoctoral levels.
- ***Leveraging Collaborations:*** Create a variety of opportunities for national and international collaboration. Deciding factors include whether investments augment other NSF activities; leverage other community, industry, federal agency, or international investments in research, education, and infrastructure;

and broaden participation in science and engineering.

- ***Potential for Impact and Transformation*:** Promote ideas that are intellectually compelling, innovative, and imaginative. Deciding factors include the extent to which investments may transform a field of science or engineering; are broadly significant or of great interest to the community; position the U.S. at the forefront of an emerging field; promote teaching, learning, mentoring, training and outreach; contribute to national research and development priorities; sustain economic competitiveness; or enable socially important outcomes.
- ***Urgency and Readiness:*** Capture timely opportunities. Deciding factors include whether timing is critical to achieve optimum results, or investment is necessary to maintain long-term stability and progress in critical areas.

IV. Translating the Plan into Action

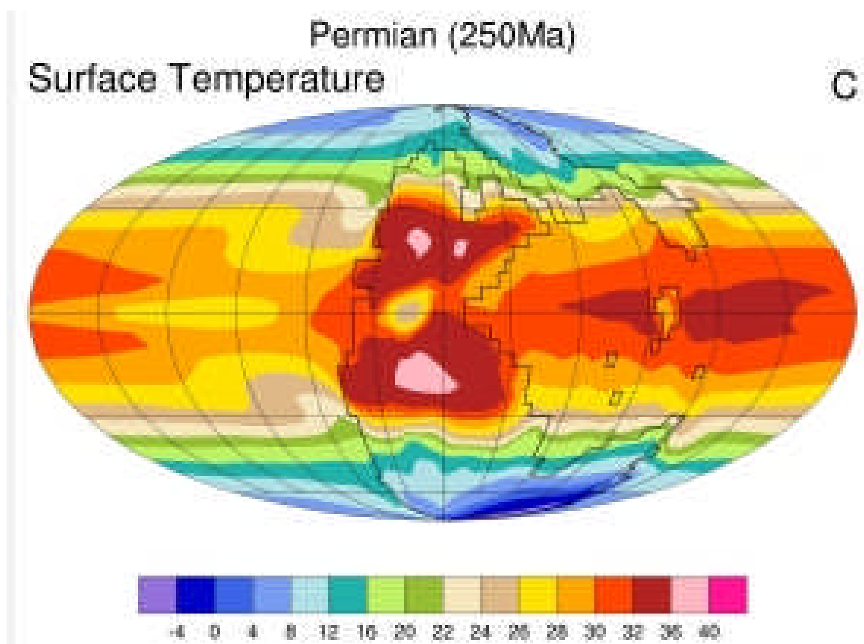
The opportunity to translate this plan into action is exciting. The Strategic Plan guides Directorate planning, the annual performance budget, and individual performance plans that link to the mission, vision, goals and objectives. Implementation of this plan is the responsibility of the Assistant Directors, Office Heads and the agency groups responsible for planning and performance. Staff will be held accountable through their individual performance appraisals, and annual metrics will appear in the budget.

An essential part of communicating is listening. In developing the plan, we have listened carefully to our community and our staff as they have given us comments on the last plan and feedback on drafts of

Climate Modeling

Knowledge of climate variability and change is of increasing importance as a basis for national and international decision making. Current and future trends in rainfall, temperature, storm frequency and intensity, snow cover and wind patterns – to name only a few – are of the utmost importance to a host of social, economic, and policy priorities, from insurance costs and agricultural production to the availability of drinking water and the spread of infectious disease. Recent advances in understanding the enormously complex interactions among the myriad components of the climate system have given researchers unprecedented insight into weather patterns and their causes. But numerous uncertainties remain, dozens of possible cause-and-effect relations remain unconfirmed, and important connections between major components (for example, the effect of ocean currents on terrestrial wind patterns, or airborne aerosols on cloud reflectivity) are insufficiently understood.

We cannot experiment on the weather; holding one variable constant while changing another. Instead, NSF supports sophisticated supercomputer simulations, called climate models, that allow researchers to study and predict global and regional climate patterns. One of the most ambitious is the Community Climate System Model – a fully-coupled, global climate model that provides state-of-the-art computer simulations of the Earth's past, present, and future climate states. The model is funded by NSF with additional support from the Department of Energy, NASA, and NOAA., It is housed at the National Center for Atmospheric Research (NCAR) and belongs to the entire community of climate scientists, rather than to a single institution. The model's underlying computer code and simulations data are freely available on the Web. As a result, hundreds of specialists at various institutions in the United States and overseas can use CCSM for their climate experiments.



The CCSM image shows temperatures in degrees Celsius at the time of the Permian extinction (~251 million years ago).
NSF news

the new plan. The plan has been developed in consultation with OMB and Congress and was coordinated with the development of the National Science Board's 2020 Vision. Communication after the release of the plan will continue with NSF staff, the National Science Board and the larger community through a variety of mechanisms. The posting of the plan on the NSF website will be communicated broadly to the staff and the external community. The plan will be presented to the Board and our Advisory Committees at their regular meetings, and will be discussed throughout NSF in staff meetings and special presentations.

NSF will use a variety of approaches to achieve its goals and, under law, evaluate its performance against a set of yearly goals and metrics specified in the annual budget. Basic research presents challenges in that outcomes from basic research often take years, sometimes decades, to understand and fully appreciate. NSF supports research on fundamental questions where directions and outcomes may be unexpected. This makes retrospective assessments of portfolios by experts (see Appendix for details) valuable especially when combined with the prospective assessments of projects inherent in the merit review process.

Strategic planning is an ongoing process. In concert with evaluating our progress against this plan, we will continue to solicit feedback from our staff; our advisors; and from the broad science, engineering and education communities to inform our next plan. As the world of science and engineering continues to change, NSF will strive to always achieve the same excellence in planning, execution, and evaluation that we expect from the programs we fund.

Appendix: Expert Evaluations and Assessments

Excellence in management and fiscal responsibility are essential to sustain and enhance NSF's reputation for global leadership. NSF uses a variety of methods to determine the quality and effectiveness of its investments throughout their lifetime. Multiple levels of expert review and external evaluation provide guidance for continuous improvement in decision-making and management.

A. Merit Review

NSF's merit review system is considered an internationally recognized best practice for the selection of projects. Proposals are evaluated using two criteria: the intellectual merit of the proposed activity and its broader impacts. Intellectual merit encompasses the potential of the research to advance knowledge, qualifications of researchers, organizational capacity, and the originality and creativity of the proposed activity. Broader impacts include aspects of teaching and learning, integration of research and education, technology transfer, societal benefits, technological innovation, tool development, and opportunities to include a diversity of participants, particularly from underrepresented groups in science. Proposals may also be evaluated according to additional criteria that are specific to the funding opportunity.

The merit review process helps assure that awards made by NSF are of the highest quality, are relevant to NSF goals and objectives, and have an appropriate balance for the resulting portfolio. The quality of the merit review process and its effectiveness in achieving NSF's strategic goals are evaluated through two additional levels of review: Committees of Visitors (COVs) and Advisory Committees (ACs).

B. Committees of Visitors (COVs)

Each COV consists of external experts who review actions taken on proposals for one or more programs. These experts are selected to ensure independence, programmatic coverage, and balanced representation. They most often represent academe, industry, government, and the public sector. COVs conduct detailed reviews of the materials associated with individual proposal actions. They assess the integrity and efficiency of the system for proposal review and the accomplishments of the awardees. COV members are asked to justify their assessments and provide supporting examples or highlights that illustrate performance and progress toward performance goals.

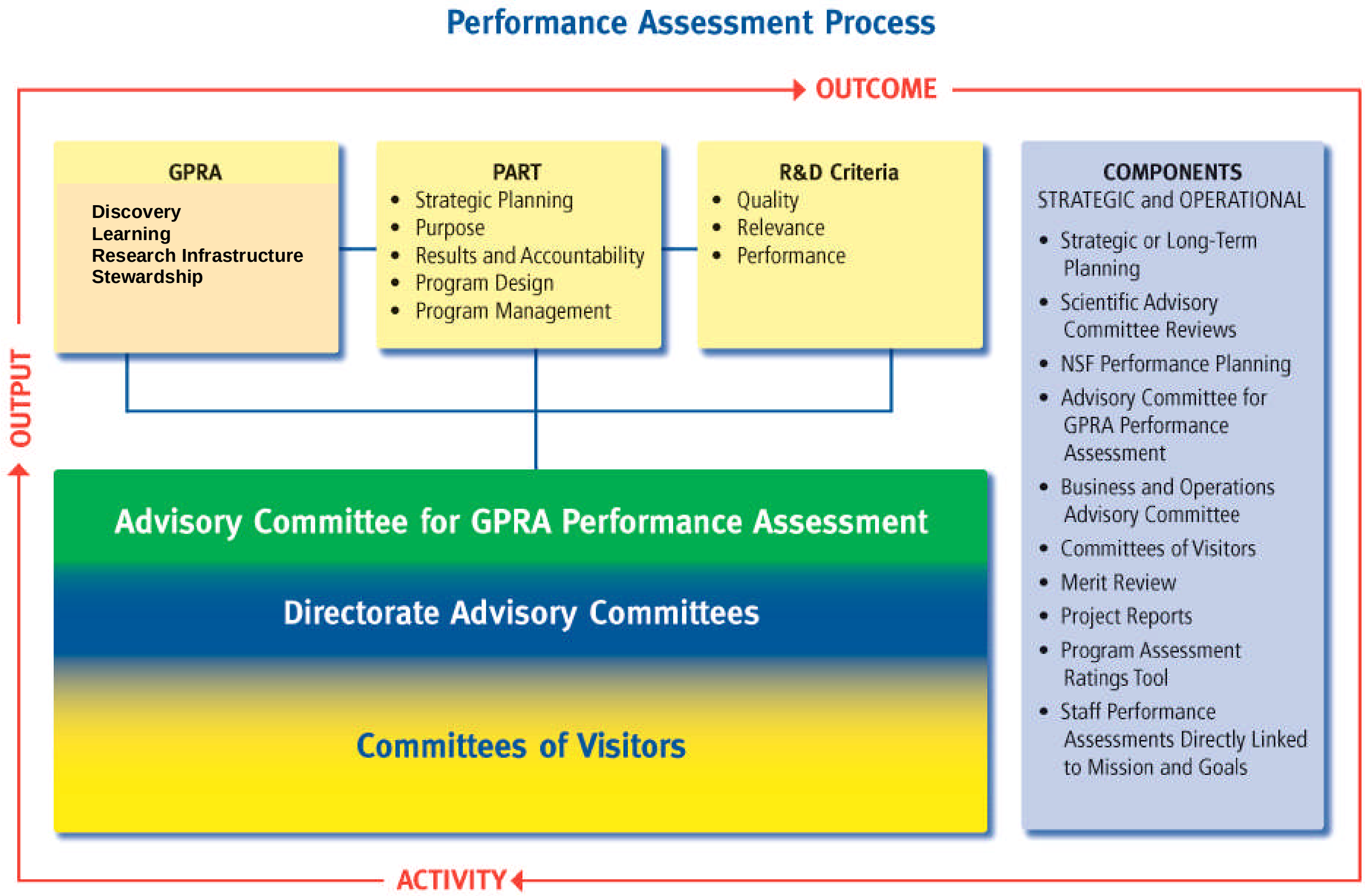
COVs assess approximately one-third of NSF's programs each year with a major focus on evaluating the merit review process. NSF Assistant Directors (ADs) respond to each COV report with plans for improvement covering the next three years. COV reports and AD responses are publicly available on the NSF web site. This transparency is essential for accountability and to maintain public confidence in NSF's polices and practices.

C. Advisory Committees (ACs)

Directorates, Offices and some Foundation-wide programs have Advisory Committees composed of external experts. ACs not only review COV reports and examine Directorate and Office responses to COV recommendations, but also provide advice on priorities and program effectiveness.

The Advisory Committee for GPRA (Government Performance and Results Act) Performance Assessment, AC/GPA, provides advice and recommendations on NSF's performance in accomplishing its goals and objectives. This external committee primarily reviews accomplishments from NSF-funded research together with COV reports and management's responses. Their review identifies potential systemic issues and helps to assure that the COV process is of consistently high quality across Directorates and Offices.

The Advisory Committee for Business and Operations, AC/B&O, includes members from the research administration, education management and



GPRA: The Government Performance and Results Act of 1993

PART: Program Assessment Rating Tool

R&D: Research and Development

business communities, including business professionals and academics in the field. The committee provides advice related to NSF's business practices and operations, including innovative approaches to the achievement of excellence in internal operations and stewardship.

D. Additional Assessments

NSF values the opinion of the science, engineering and education communities. We pay careful attention to the advice offered in reports by the National Academies, including National Research Council reports, national and international science organizations, professional societies, workshops, interagency working groups and advisory committees. We use this input to inform strategic planning and to assess management practices.

A variety of other assessment tools evaluate management excellence. NSF's performance record includes eight continuous years of "clean" audit opinions. NSF has also achieved the highest ratings in the in the President's Management Agenda[3] for Human Capital, Financial Performance, Electronic Government and Budget-Performance Integration, and received the highest rating of "Effective" in all programs rated by OMB in its Program Assessment Rating Tool (PART)

[3] NSF was the first agency across government to achieve "green" (highest rating) in Financial Performance and also the first for "green" in Electronic Government (see www.results.gov). NSF remains "red" (lowest rating) for status on Competitive Sourcing, public-private job competitions.

evaluations[4]. The most important PART measures, together with other annual goals, are included in NSF's annual performance budget and the agency Performance and Accountability Report. ACs, COVs and other on-going assessment processes are valuable in ensuring continued success in PART evaluations and annual progress toward the long-term Strategic Goals.

Beyond setting agency-wide annual goals in the budget, NSF takes the additional step of obtaining independent verification and validation of its performance results each year before reporting them to OMB, Congress and the public through the Performance and Accountability Report (PAR).

One example of an annual goal and an indicator of efficient, effective management of the merit review process is dwell time, the time from proposal submission to the time a funding decision is available to the proposer. The quantitative measure for dwell time is balanced by also ensuring a high quality review process. Timely responses to Principal Investigators are critical but must not adversely impact review quality. Results from this and other quantitative goals are available to NSF management and staff through an online Enterprise Information System that shows performance at NSF-wide, Directorate, Division and program levels.

Finally, in addition to the extensive annual PAR, NSF will report on annual Foundation performance through a concise Performance Highlights document. Over the next five years, NSF will continue to improve management excellence, with a continuing emphasis on linking together information technology, human capital and financial management to support outcomes resulting from the core processes of merit review, award management and oversight, performance assessment and accountability, resource allocation, knowledge management, and internal and external communication strategies.

[4] As of the FY2007 PART evaluations, NSF is the only agency with multiple PART programs to earn the highest rating across-the-board in all programs (see www.expectmore.gov).